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China's low-carbon-city development with ETS: Forecast on the energy consumption and carbon emission of Chongqing

Meicong Liang[a], Yu Wang[a]*, Gehua Wang[a]

[a]*Institute of Energy, Environment and Economy, Tsinghua University, Beijing, China*
Energy Science Building C304, Tsinghua University, Beijing, 100084, China

Abstract

The low carbon development roadmap is an extremely important topic of fundamental research in China due to China's lack of energy resources, serious environment pollution, and huge greenhouse gas (GHG) emission. In this paper, an overview of energy supply and demand in Chongqing, a summary of current social and economic development planning and energy policies were provided, as background to the implementation of Long-range Energy Alternatives Planning System (LEAP) model of Chongqing. The LEAP model is used to compare future energy demand and supply patterns, as well as GHG emissions peak arriving. Results of scenarios featuring business-as-usual (BAU) policies, low carbon development (LCD) strategy, carbon emission trading scheme (ETS) pilot, and coal consumption controlling (CCC) action are provided and compared, along with sensitivity cases exploring the impacts of various scenario assumptions. Results show that, Chongqing's emission peak would arrive at nearly 2025 in BAU scenario; while keeping the carbon intensity of GDP reduction continuously, utilizing more clean energy, and implementing ETS could help Chongqing to achieve energy consumption and GHG emission more cost effective than BAU scenario. This study provides a quantitative, city-specific analysis of low carbon development roadmap, which can be used to support policymakers' decision.

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1. Introduction

Chongqing, located in Southwest China, is one of the five municipalities in China. It separated from Sichuan province since March 1997, and has experienced great changes in economic gross and energy consumption under the Great Development in West China Strategy. In 2012, the Gross Domestic Product (GDP) of Chongqing reached 1048.0 billion Ren Min Bi (RMB) (2010 constant price); the energy consumption was 82.8 million tons of coal equivalent (tce). Abundant with mineral, energy resources and labor force, heavy industries have always been the pillars of Chongqing's industry. In 2011, Chongqing

* Corresponding author. Tel.: +86-10-62772757; fax: +86-10-62772759.
E-mail address: y-wang@tsinghua.edu.cn.

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was selected to be the first bulk of Low-carbon Development Pilot project and ETS pilot project, which reveals the distinctive influence Chongqing has in economy, energy policy and development within China, especially in western China.

Similar studies paid much attention on national level and first-tier cities [1, 2], and few focused on other cities like Chongqing. So our research is necessary, and the results would have reference significance to the low carbon development in western China.

In this article we intend to use the LEAP model to forecast Chongqing's future energy demand, CO_2 emission as well as peak arriving with four scenarios and give advices on low carbon development roadmap for Chongqing. Our article is structured in three parts, firstly we introduce the background and significance, then elaborate the methodology and scenario setting, finally draw conclusions and suggestions based on the results.

2. Model and Methodology

The LEAP model is a bottom-up simulation tool with a flexible model structure which can be adjusted to different needs and has been widely used in energy analysis [3]. It is based on physical accounting and can be used as simulation, forecasting, scenario analysis and policy analysis tool. The key input parameters in LEAP model are the total activity level per fuel and end-use, the energy intensity per activity, the demand costs and the environmental loadings or emissions. For every technology branch, the energy demand is calculated separately, when all technology branches are calculated, the total final energy demand is computed for each fuel. The total activity level for a fuel is calculated as the product of all activity levels in all branches. *ED* represents energy demand, *TA* represents total activity level and *EI* represents energy intensity; and *b*, *s*, and *t* respectively stands for technology branch, scenario and year. Activity level refers to the social or economic activities which consuming energy; and energy intensity refers to the energy consumed for each unit of activity.

$$ED_{b.s.t} = TA_{b.s.t} \times EI_{b.s.t} \tag{1}$$

In this article, we modify the sectors into six sub-industries, which are agriculture (Agri), manufacture industry (Manu), construction industry (Cons), service industry (Serv), transportation (Trans) and household consumption (Hous). For energy consumption accounting, more than 20 types of energy are involved in this model, and are classified into primary energy and secondary energy. CO_2 emissions are calculated using standard emission factors from the IPCC and estimates from Chinese governmental agencies.

3. Statistics and Scenarios setting

We designed four scenarios respectively featuring different kinds of policies. BAU scenario, as a reference scenario, allows Chongqing to develop without any energy or emission constraint. LCD is a development pattern featuring low energy, low pollution and low emissions, which is a new energy policy foundation of China. ETS, a government-launched market approach, sets emission caps, allocates and sells emission permits to let the market guide emission reduction. CCC is a newly launched energy policy in China aiming to limit the coal consumption and promote the optimization of energy mix.

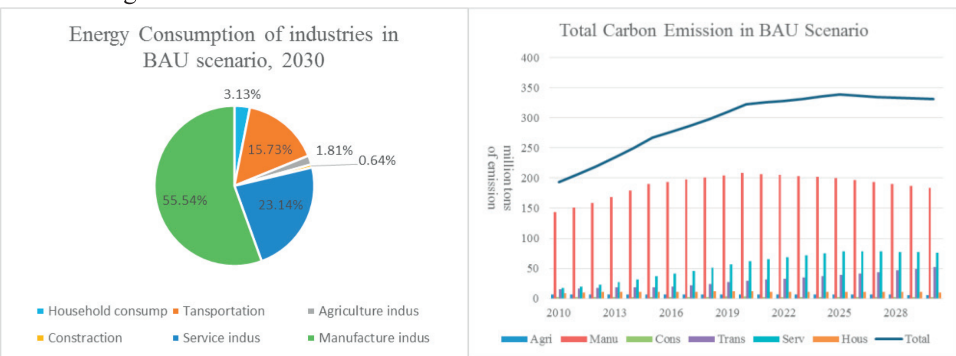
According to Chongqing's 12th Five-Year Plan (FYP), Chongqing's GDP annual growth rate will be 15%, and by 2015 the total industrial output would be 2500 billion RMB. Our forecasting would start from the end of 12th FYP till 2030, and parameters are set according to the history development data of Chongqing and mid-long term plan for Chongqing and China as well. Table1 gives the specific description of the four scenarios. The four scenarios shares the same basic economic parameters' setting, while differs in industry structure, energy mix and other parameters. Scenario design and calculation are independent from each other.

Table 1. Parameters designing in four scenarios

Parameters	Time	BAU	LCD	ETS	CCC
Population (annual increase,‰)	2015-2020	5.5			
	2020-2030	5			
GDP (annual increase, %)	2015-2020	9.2			
	2020-2030	4.7			
Urbanization (%)	by 2030	70			
Industry structure (Argi:Manu:Cons:Trans:Serv)	by 2030	3:55:4:3:35	2:30:4:4:60	3:55:4:3:35	3:55:4:3:35
Energy mixture (coal:oil:gas:elec:renew)	by 2030	55:10:20:13:2	55:10:20:13:2	55:10:20:13:2	50:10:23:12:5

4. Results Analysis

According to our study, by 2030, the GDP of Chongqing would reach 3667 billion RMB and GDP per capita would be 99.7 thousand RMB. The total energy demand would be in the range from 117.2 to 138.2 million tce, rising 60% compared with 2010. The peak of energy consumption would arrive around 2025, and peak values range from 126.1 to 139.9 tce.



(a) (b)

Fig. 1. (a) Energy consumption; (b) total emission

By 2030, the total emission of Chongqing would be in the range from 305.4 to 338.6 million tons of CO_2, and the peak also comes around 2025. Fig.1 shows the trend of CO_2 emission and energy consumption in BAU scenario. From 2010 to 2020 the curve is steep due to the rapid economic growth and the lack of advanced technology; while from 2020 to 2030 the curve is smoother, when the effects of mitigation measures become dominant. In the BAU scenario, 55.6% emission comes from manufacture industry with the emission intensity, 9.0 tons CO_2 per thousand RMB. Service industry emit 23.14% CO2 and its emission intensity is 5.7 tons CO_2 per thousand RMB. On the basis of the sensitivity analysis in BAU scenario, when 1% industry proportion shifts from manufacture industry to service industry in 2030, nearly 1.3 million ton of carbon emission would be reduced.

Among the four scenarios, ETS scenario works best. Its peak emission value is 305.4 million tons, 33.2 million tons less than BAU; and its peak energy consumption is 126.1 tce, 13.8 tce less than BAU. LCD scenario also has tangible effect; compared with BAU scenario's peak value, it reduces 33.1 million tons CO2 and 13.7 tce energy consumption. In CCC scenario, by 2030, coal will make up 50% of energy consumption, total emission will be 321.5 million tons CO2.

5. Conclusions

The four scenarios feature different kinds of carbon mitigation measures and affect to various extent. ETS scenario features market mechanism and its effect is the most obvious. When emissions are capped and initial emission credits are allocated, then the trading market is used to help re-allocate the emissions. The enterprises can either promote technologies or buy emission credits to achieve their goals, thus allowing market mechanism to drive industrial and commercial processes in the direction of low emissions or less carbon intensive approaches. According to the industry structure characteristics of western China, the design of ETS may set more stringent cap on manufacture industry to guide the improvement of industry structure.

LCD scenario simulates the implement of low carbon development strategy, focusing on industry structure adjustment and technology improvement. 11.5 million tons of emission reduction is attributed to the change of industry structure. And according to the sensitivity analysis, in 2030, every 1% shift in industry structure from manufacture industry to service industry would reduce 0.7 million tons CO2. So the government should introduce policies to optimize the industry structure, promote the development of service industry and improve energy efficiency for manufacture industry by eliminating backward production capacity, speeding industrial integration and providing technical support.

Thermal power generation takes almost a quarter of Chongqing's coal consumption, and it provides nearly half of the electricity generation of the city. Abundant with hydropower resource, Chongqing may utilize hydropower vigorously to replace part of the thermal power generation. Household also takes 15% of the total coal consumption, generally used for cooking and heating, which can be substituted by natural gas, for its sufficiency and low-carbon.

All the measures mentioned above are proved to be effective in energy conservation and emission mitigation. Though they are designed to affect independently in our study, the implement of these policies and strategies could be integrated and bulked in packages, and may result more with less.

Acknowledgements

These and the Reference headings are in bold but have no numbers. Text below continues as normal.

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Biography

Meicong Liang, PHD candidate, focusing on regional emission forecasting and emission transfer via international trade. Yu Wang, assistant professor, focusing on regional low-carbon development roadmap and renewable energy resources technical evaluation. Gehua Wang, professor, focusing on biomass energy and agricultural energy resources.